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Path coefficient analysis of three faba bean cultivars sprayed with Nano-iron

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In the 2020/2021 agricultural season, a farmer's field in Al-Rumytha, 25 km north of Almuthanna governorate, was used to test the effects of spraying Nano-iron at three concentrations (0, 100, 200) mg Fe l-1 on three faba bean cultivars (Equadelji, Luz De otono, Equadules) on growth and productivity. The split-plot experiment used three replications of the Randomized Complete Block Design. The mai (Gutierrez) plots had cultivars, and the sub-plots had Nano-iron fertilizer. Spraying Nano-iron at 200 mg Fe l-1 significantly increased the average number of pods per plant, weight of 100 seeds, and total seed yield, with the highest averages of 18.10 pods per plant-1, 113.10 g, and 3420 kg ha-1, respectively. Nano-iron spraying does not affect pod length or seed count. The cultivars studied varied greatly. Equadules outperformed the other two cultivars in pod length, pod count per plant, and seed yield with 3795 kg ha-1. The cultivars had similar seeds per pod and 100 seed weights. The interaction significantly affected pod number and seed yield. Spraying Equadules cultivar with 200 mg Fe l-1 yielded 22.00 pods plant-1 and 4280 kg ha-1 of seed. The genetic correlation study found a positive correlation (0.308, 0.745**, 0.098, and 0.165) between total seed yield, pod length, pod number per plant, seeds per pod, and 100 seed weight. 100 seeds' weight, pod length, and pod number per plant were (0.439* and 0.139). Pod number and pod length were also strongly correlated (0.673**). Path Coefficient analysis showed a positive and significant effect of pod quantity per plant on seed yield (1.062 and 0.370). Seed yield was directly affected by pod length and seeds per pod (0.254 and 0.109). Based on the above, subsequent breeding programs can use pod numbers per plant and weight per 100 seeds as selection guides to select seed yield.
Keywords: Path coefficient analysis; faba bean cultivar; nano-iron; spray fertilizer; sprayed by Nano-iron.

INTRODUCTION

The faba bean (Vicia faba L.), which is a member of the legume family, is a crop that can be grown. The seeds of this plant contain high levels of protein (up to 40%) and carbohydrates. The percentage reaches 56% in most cultivars (Natalia *et al.*, 2008). It will raise the relevance of this crop because it has a high nutritional value for human life and is a less expensive source of protein than pricey animal protein. Additionally, faba beans have considerable fiber, vitamins, and mineral components. Nitrogen in the atmosphere is fixed by the root nodes in the soil (Carmen *et al.*, 2005).
Nanotechnology applications in agriculture are one of the current ways to enhance growth and yield by increasing water and nutrient uptake and being economical. Nanotechnology applications in agriculture are one of the modern approaches (Noaema *et al.*, 2020). When compared to other types of fertilization, foliar fertilization is among the approaches that are both the most effective and the most cost-effective. When the plant's roots have difficulty keeping up with the growing demands, it is essential to feed the plant with the essential nutrients it requires (Martin, 2002). Iron is an essential nutrient for leguminous plants because it is a necessary component in the formation of the nitrogenase enzyme, which plays a role in the process of fixing the nitrogen that is present in the atmosphere, and because iron plays an essential role in the formation of the leguminous hemoglobin pigment (Malvi, 2011).
Planting high-yielding varieties of faba bean and following effective field practices are the foundations for increasing faba bean production. The goal is to get the latent energies of such cultivars and determine the extent of their adaptation to the environmental circumstances of the region. There is a direct relationship between the phenotypic and anatomical

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characteristics of each cultivar and the ability of cultivars to absorb water and nutrients and increase the process of photosynthesis and the transfer of its products to obtain the highest productivity and the best quality, which is one of the primary goals of plant breeders. [Cultivars'] ability to absorb water and nutrients and increase a process of photosynthesis and the transfer of its products to obtain the highest productivity and the best quality is one of the (Al-Sahoki, 2006).

Due to the lack of studies that dealt with the subject of this study, which is the use of nano-fertilizers, because of their significant impact on the growth and yield characteristics of this important crop. Therefore, this experiment aimed to know cultivars response of faba bean to foliar feeding by Nano-iron fertilizer.

MATERIALS AND METHODS

To investigate the impact of spraying with Nano-iron fertilizer in three concentrations, an experiment field was set up in a farmer's field in the Al-Rumytha district, 25 kilometers north of the Almuthanna governorate (0, 100, 200 mg Fe l-1), symbolized by the symbol (Fe 0, Fe1, Fe2) on three cultivars of faba bean, were (Equadelji, Lus De OTONO, Equadules) symbolized by (V1, V2, V3) respectively faba bean productivity and growth. Three replications of the experiment were conducted using a split-plot design that followed the rules of the complete randomized block design, or R.C.B.D. The main plots were planted with the cultivars, and the doses of Nano-iron fertilizer were placed in the sub-plots.

The samples of depth (0-30) cm was taken randomly and mixed to symbolize the experimental field. The physical and chemical analyzes required before planting for the experimental field were carried out and shown in (Table 1).

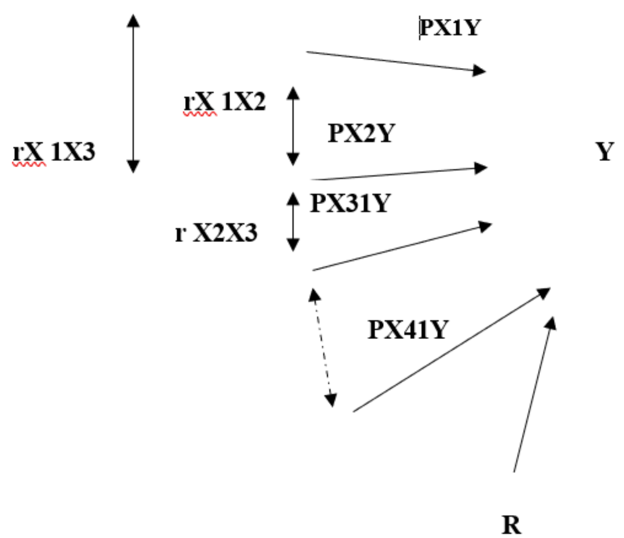
Table 1. The field's physical and chemical properties.

Characteristics	Values	Units
pH	7.3	
E.C.	4.0	Desimines m^{-1}
CEC	21.0	Centimeter (+) kg^{-1}
Nitrogen	20.0	mg kg^{-1} soil
Phosphorus	8.4	
Potassium	171.0	
Iron	1.0	
Sand	17.0	kg^{-1}
Silt	45.0	
Clay	38.0	
Texture	Silty clay loam	

The soil was plowed with two plows, smoothing and dividing. The cultivation process was carried out on October 17, 2020, after dividing the field into three replicates, the area of each experimental unit ($3 \times 3 = 9\ m^2$) area in each replicate contains 9 experimental units. Each experimental unit included 4 lines; the gap between them was 75 cm, and the holes were 20 cm apart. Utilizing urea fertilizer, the nitrogen fertilization process was carried out in accordance with the fertilizer recommendation of 60 kg N ha^{-1}. With 46% nitrogen in two batches, the first 15 days after planting, and the second batch after 1 month from the first batch, and phosphorous using triple super phosphate fertilizer at once before planting and according to the fertilizer recommendation, 80 kg P2O5 per ha^{-1} (Al-Abedy, 2011).

When the plants had 50% of their flowers open, the Nano-iron spraying procedure was done by the Iranian business Biozar. Using the GenStat program, the data were statistically evaluated in accordance with the chosen design, and the arithmetic averages were compared using the LSD test at the 5% level of probability.

The path coefficient analysis was studied, as well as to determine the trait or traits most influencing yield; this was planned by (AL-Rawi 1987):



As Xi: Causative factors (Five studied traits); Y: Responsive factor (grain yield); R: The remaining factors; ⟵ : A vector representing a path parameter from the Causative to the effector; ↕ : A vector representing the coefficient of correlation between the two traits rxixi

From the above chart, the grain yield y is the result of the causative factors x1, x2, x3, and x4

rx1y = px1y + px2yr12+ ……..+ px4yr14

rx2y = px1yr21 + px2y+ ……..+ px4yr24

rx4y = px1yr1 4+ px2yr24 +……..+ px4y

rRy = PRY = $(1-\sum PxiYrxiy)^{1/2}$

These simultaneous equations are put into a matrix as follows:

$$\underset{A}{\begin{pmatrix} rx1y \\ rx2y \\ \cdot \\ rx4y \end{pmatrix}} = \underset{B}{\begin{pmatrix} r\,x1x1 & rx1x2 & \ldots & rx1x4 \\ r\,x2x1 & rx2x2 & \ldots & rx2x4 \\ & & & \\ r\,x4x1 & rx4x2 & \ldots & rx4x4 \end{pmatrix}} \times \underset{C}{\begin{pmatrix} rx1y \\ rx2y \\ \\ rx4y \end{pmatrix}}$$

To calculate the values of matrix C (the values of the path coefficient), we compute the inverse of matrix B.

$$\begin{pmatrix} Px1y \\ Px2y \\ \cdot \\ Px4y \end{pmatrix} = \begin{pmatrix} 1 & r\,x1x2 & \ldots & rx1x4 \\ r\,x2x1 & 1 & \ldots & rx2x4 \\ & & & \\ Rx4x1 & rx4x2 & \ldots & 1 \end{pmatrix} \times \begin{pmatrix} rx1y \\ rx2y \\ \cdot \\ rx4y \end{pmatrix}$$

$$C = B^{-1} \times A$$

RESULTS AND DISCUSSION

Pod length (cm): Figure 1 showed the superiority of cultivar Equadules (v3) over other cultivars in pod length with an average of 18.78 cm. The cultivar Equadelji (v1) recorded the lowest trait average of 13.70 cm. It is affected by differences in environmental conditions and other external factors, and the variance of this trait between cultivars may give an important indication of the variation in their genetic structure (Al-Hasany *et al.*, 2020).

Nano-iron concentrations, and interaction between iron concentrations and cultivars, no significant differences were found in pod length (Fig. 1).

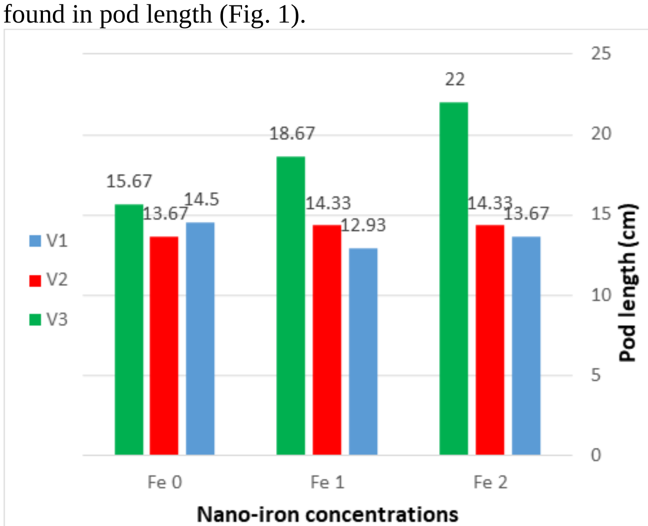


Figure 1. Effect of faba bean cultivars, spraying by Nano-iron, and their interaction on pod length (cm).

Pods number in plant (pod plant^{-1}): Figure (2) showed that spraying with iron significantly increased the presence of this characteristic by increasing the concentration, as spraying with a highest concentration (Fe 2) achieved the highest average of 18.10 pods plant^{-1}, while control treatment (Fe 0) recorded the lowest average at 15.14 pods plant^{-1}. The cause may be due to the significant function that iron plays in activating numerous enzymes, which helped to speed up photosynthesis, which in turn increased the movement of photosynthetic products from the source to the sink and increased the number of pods in a plant.

The results in the exact Figure indicate the superiority of the plants of cultivar Equadules (v3) in pods number; it recorded the highest average of 18.22 pods plant^{-1}, which was similar to the cultivar Equadelji (v1 average)'s of 17.76 pods plant-1 and the highest average. While cultivar Luz de otono (v2) was recorded, the lowest average was 14.22 pods plant^{-1}. The variation of the cultivars among them in pod number could be attributed to the difference in the genetic mechanism controlling this important trait for leguminous crops, which agreed with what was found (Al-Hasany *et al.*, 2021).

It was also found that a significant effect of interactions between factors. A combination of Equadules cultivars sprayed with Nano-iron at the highest concentration (Fe2×V3) showed a highest average of pods number at 22.00 pods plant^{-1}, while the combination Luz de otono cultivars sprayed with distilled water only (Fe 2×V2) gave a lowest average at 13.00 pods plant^{-1} (Fig. 2).

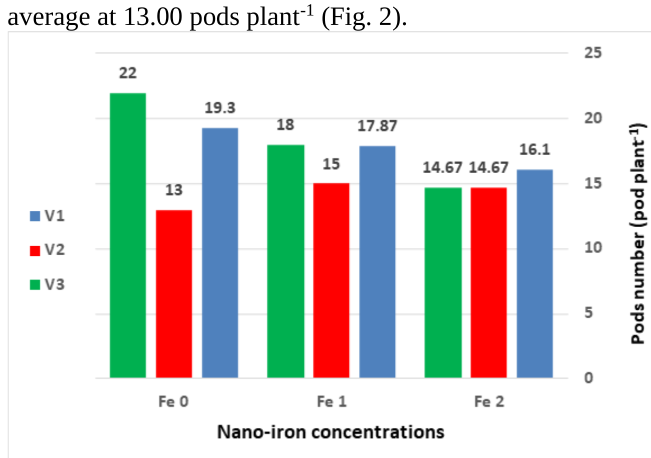


Figure 2. Effect of faba bean cultivars, spraying by Nano-iron, and the interaction on Pods number in plant (pod plant^{-1}).

Seeds number in pod (Seed Pod^{-1}): Figure 3 shows no significant differences between concentrations of Nano-iron fertilizer, cultivars, and their interaction in characteristic seeds number in pod.

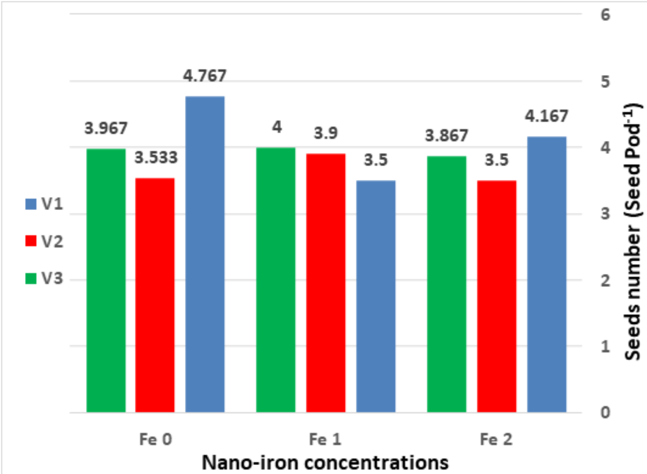


Figure 3. Effect of faba bean cultivars, spraying by Nano-iron, and the interaction on seeds number in pod (Seed Pod^{-1}).

***Weight of 100 seeds (g)*:** The effects of spraying with Nano-iron at various concentrations on the weight of 100 seeds were shown in Figure 4 to differ significantly. The impact of treatment (Fe 2) produced the most significant average for this trait, 113.10 g. They did not significantly differ from the concentration (Fe 1), which produced an average of 112.40 g, but they did differ from the control treatment (Fe 0), which produced the lowest mean of 102.70 g. (Fusial *et al.*, 2012). On the other hand, there were no discernible variations in this feature between cultivars or when Nano-iron was combined with cultivars (Table 5).

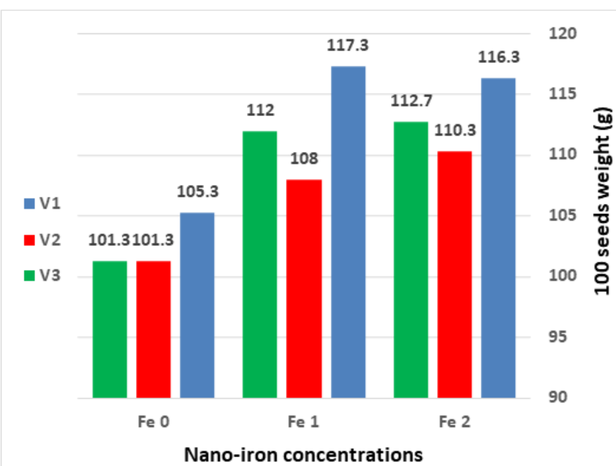


Figure 4. Effect of faba bean cultivars, spraying by Nano-iron, and the interaction on weight of 100 seeds (g).

Yield of total seed (kg ha^{-1}): Figure (5) indicates the direct increase of this trait when the concentration of spraying with Nano-iron increases. The control treatment (Fe 0) produced the lowest average for this feature, which came to 2902 kg ha-1, while the spraying treatment (Fe 2) produced the highest average of 3420 kg ha-1. Spraying concentrations are preferable because of their superior pod count on the plant (Figure 2) and weight of 100 seeds (Figure 4), which increased total seed yield and are consistent with (Al-Hiji, 2014) and (Aljaberi *et al.*, 2020).

The exact Figure showed the superiority of Equadules (v3) in this trait, recording a highest average at 3795 kg ha-1, but Equadelji (v1) cultivar recorded the lowest average yield of total seed yield of 2744 kg ha^{-1}. Perhaps the reason is due to the superiority of cultivar Equadules of pods number in the plant (Fig. 2), and this confirms that cultivar Equadules is more efficient than other cultivars due to its genetic ability that made its plants work to achieve a balance between source and sink and the high rate of physiological and biological processes, which was positively reflected on yield of total seed (AL-Hasany, 2018).

Figure (5) results showed the cultivar Equadules, which was sprayed with the highest concentration of Nano-iron (Fe2×V3), significantly outperformed them, as they achieved a highest mean at 4280 kg ha^{-1} than a combination between cultivar Equadelji sprayed with distilled water only (Fe0 × V1) recorded the lowest average reaching 2554 kg ha^{-1}.

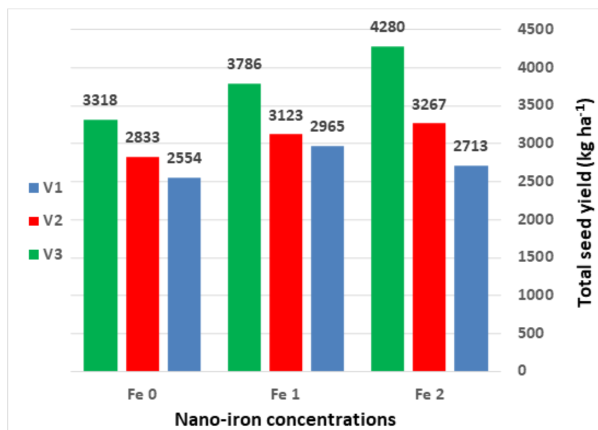


Figure 5. Effect of faba bean cultivars, spraying by Nano-iron, and their interaction on yield of total seed (kg ha^{-1}).

Seed yield, pod length, pods per plant, seeds per pod, and the values of the genetic correlation coefficients between the total seed yield and the other examined parameters, and 100 seeds weight were (0.308, 0.745**, 0.098 and 0.165), respectively, as shown in Table 2. These findings indicate a substantial and positive association between seed yield, pod length, pods per plant, and seeds per pod. In addition, it was found that there was a positive and substantial association between the weight of 100 seeds, the length of the pod, and the number of pods produced by the plant, with the correlation amounting to (0.439 * and 0.139) correspondingly. In addition, a negative association was found between the weight of one hundred

seeds and the total number of seeds in the pod, which amounted to (- 0.116). It was shown that there was a positive and substantial correlation between the number of seeds in each pod, the length of the pod, and the number of pods produced by each plant; however, this association was only (0.195 and 0.120, respectively). In addition, it was found that the length of the pod and the number of pods produced by the plant have a positive and very significant connection (0.673**). These findings are consistent with those found in (Abbas, 2012), and it is possible that the influence of genetic variables and the effect of nano-iron fertilizer are to blame for the association found between the yield and its components that were evaluated.

Table 2. **Values of the genetic correlation between outcome and studied traits.**

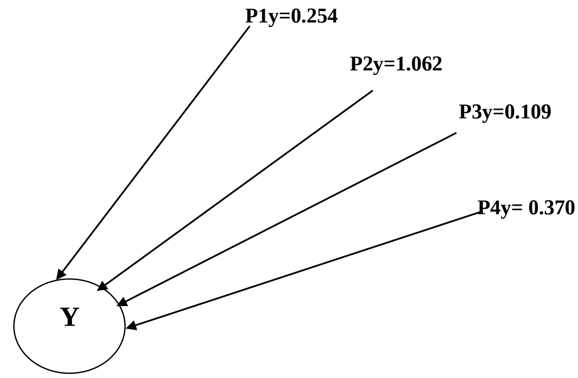
	Pod length	Pods in plant	Seeds in pod	Weight of 1000 seeds
Pods in plant	0.673**			
Seeds in pod	0.195	0.120		
1000 seeds weight	0.439*	0.139	-0.116	
Seed yield	0.308	0.745**	0.098	0.165

It can also be seen that the researched characteristics have a direct impact on the total seed output (Table 3). The direct influence of pod number in plant and weight of 100 seeds was positive and highly significant on the seed yield, which amounted to (1.062 and 0.370) respectively. This resulted from the seed yield being affected by these two variables. In contrast, the direct effect on seed yield was determined by pod length and the amount of seeds contained within each pod. It reached (0.254 and 0.109), and based on the previous, it can be directed to adopt the traits (pods number in plant and weight of 100 seed) to be as electoral guides in subsequent breeding programs to select the trait of seed yield, as it is a complex trait whose heredity depends on a large number of genetic factors and its impact on the environment. This is because seed yield is a complex trait whose heredity depends on many genetic factors, and its impact on the environment is significant, consistent with what was said earlier (Abbas, 2012).

Table 3. **The direct effect of the features under investigation on seed yield.**

Traits	Direct effect
pod length	0.254
pods number in plant	1.062
seeds number in pod	0.109
100 seed weight	0.370

Scheme (1) the path coefficient between the yield and the studied attributes:



Whereas: P1y: pod length, P2y: pods number in a plant, P3y: seeds number per pod, P4y: 100 seeds weight of, P5y: (y) total seed yield

Conclusions: According to the study's findings, using a spray containing 200 mg Fe l-1 Nano-iron enhanced the number of pods produced by each plant and the seed weight and production. Nano-iron has no effect on the total number of seeds or the pod length.

Different cultivars exist. The Equadules cultivar produces longer pods, more significant pods on each plant, and more seeds. The number of seeds per pod and the number of seeds per 100 was comparable.

There was a positive correlation between total seed yield, pod length, pod number per plant, number of seeds per pod, and weight of 100 seeds. The quantity of 100 seeds together with their length and weight. There was a correlation between pod length and pod number. Path Coefficient studies discovered a positive and statistically significant link between the amount of pods produced and the quantity of seeds. Both pod length and seed count are directly influenced by seed yield.

***Author's Contributions statement*:** Ali R. Alhasany, Contribute to the idea, field implementation, and writing. Muhamed A. K. AL-Abody contribute to data collection and part of the analysis. Ali H. Noaema contribute to field work and linguistic and statistical review. Rawnaq M. Jazee contribute to data collection and writing. Barbara Sawicka, contribute to the scientific and statistical audit and general supervision of the research

***Conflict of interest*:** Ali R. Alhasany and other authors declares no conflicts of interest

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Consent to participate**:** All authors are participating in this research study.

Consent for publication**:** All authors are giving the consent to publish this research article in JGIAS

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